

PROTOTYPE SPACE STATION AUTOMATION SYSTEM
DELIVERED AND DEMONSTRATED AT NASA

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Abstract

The Automated Subsystem Control for Life Support System (ASCLSS) program has successfully developed and demonstrated a generic approach to the automation and control of Space Station subsystems. The automation approach was recently delivered and demonstrated by Honeywell and Life Systems Inc. for NASA JSC. The hierarchical and distributed real-time controls system places the required controls authority at every level of the automation system architecture. As a demonstration of the automation technique, the ASCLSS system automated the Air Revitalization Group (ARG) of the Space Station regenerative Environmental Control and Life Support System (ECLSS) using real-time, high fidelity simulators of the ARG processes. This automation system represents an early flight prototype and an important test bed for evaluating Space Station controls technology including future application of ADA software in real-time control and the development and demonstration of embedded artificial intelligence and expert systems (AI/ES) in distributed automation and controls systems.

Introduction

Early in 1983, NASA initiated a technology development program entitled, Automated Subsystem Control for Life Support System (ASCLSS, contract NAS-9-16895). The national commitment for a permanently manned Space Station was growing and NASA recognized that to be a successful, operational Space Station would require highly reliable and fully automated subsystems. NASA OAST (code R) and the Crew and Thermal Systems Division of NASA JSC set out to address this vital first step for the Space Station.

Following a competitive procurement, Honeywell and Life Systems, Inc. initiated a four year technology program to define, develop, and demonstrate a generic or common approach to automation and control for all Space Station subsystems including ECLSS, thermal (TPS), power (EPS), and guidance, navigation, and control (GN&C). Because of the critical importance of life support, the generic automation technique was to be demonstrated against the air revitalization group (ARG) of the regenerative ECLSS subsystem using high fidelity real-time simulators of the ARG O₂ generation, CO₂ removal, and CO₂ reduction processes.

ASCLSS Demonstration System

An early ASCLSS applications study indicated that a hierarchical architecture of distributed controllers would fulfill the automation and control requirements across a majority of Space Station subsystems. Additional automation system drivers included maximum operational autonomy from the ground, automation of routine subsystem operations and redundancy management, strong emphasis on commonality of hardware and software, accommodation for on-orbit maintenance,

use of accepted standards, and ease of subsystem performance growth and insertion of new technology.

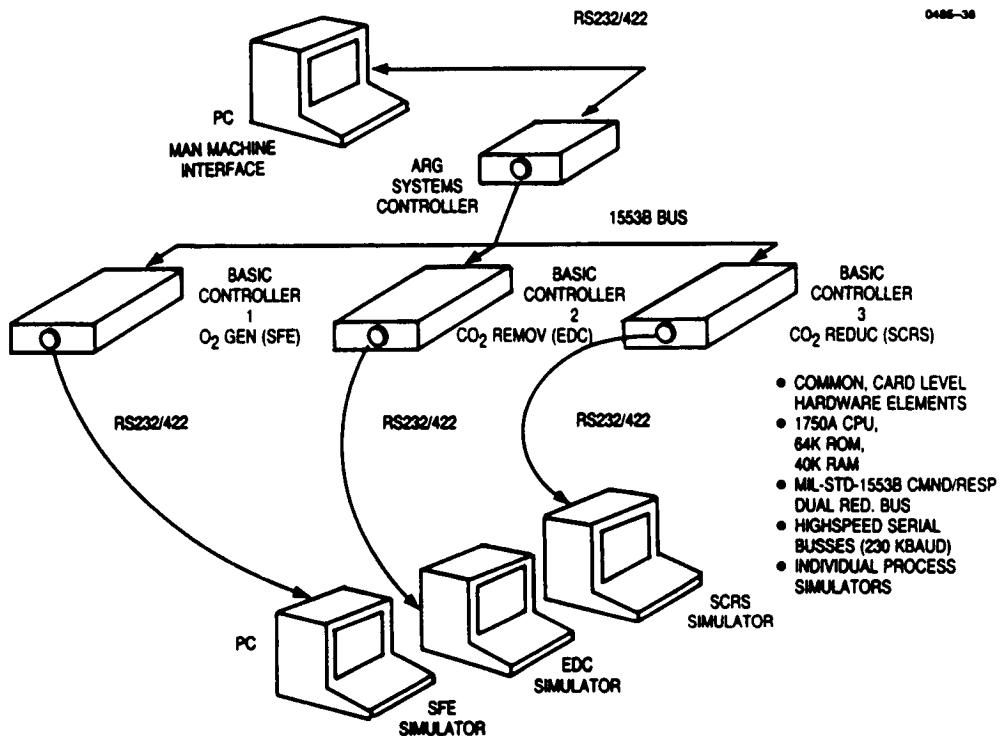


FIGURE 1. ASCLSS Automation and Control Demonstration System

The resulting ASCLSS automation system shown in figure 1 consisted of a two level hierarchy of distributed controllers implemented with MIL-STD-1750A microprocessors tied together by a high speed MIL-STD-1553B bus network. All four controllers at the basic or local level and system level are implemented in completely common hardware which supports maintainability and lower life cycle cost. The ARG processes are implemented by real-time simulations in individual personal computers. An important man-machine interface (MMI) is included in the automation system to provide the required supervisory control authority for the Space Station crew. Through the MMI, which represented the multi-purpose application console (MPAC), the crew can monitor system status and performance, and when necessary, exert override control authority or conduct system fault evaluation and maintenance procedures. The MMI also provided an effective demonstration of the control authority allocated between the crew, the system level controller and the basic or process level controllers.

The ASCLSS automation system implemented an innovative layered software architecture written in Pascal which emphasized significant levels of common software modules. Figure 2 illustrates the layered software structure developed for the automation and controls system. The real-time operating system (OS) is fully common to all controllers and is written in 1750A assembly. The OS performs all network communications and I/O data transfers and schedules/deschedules all controller tasks. The ASCLSS system control software acts as the agent for the application software between the I/O data base and the generic operating system. The system control software is the same in all local controllers and largely common in the system level controller. The only unique software in each controller is the application software and its associated table driven I/O data base. Thus, the non application-dependent software in each controller in the ASCLSS automation architecture is common.

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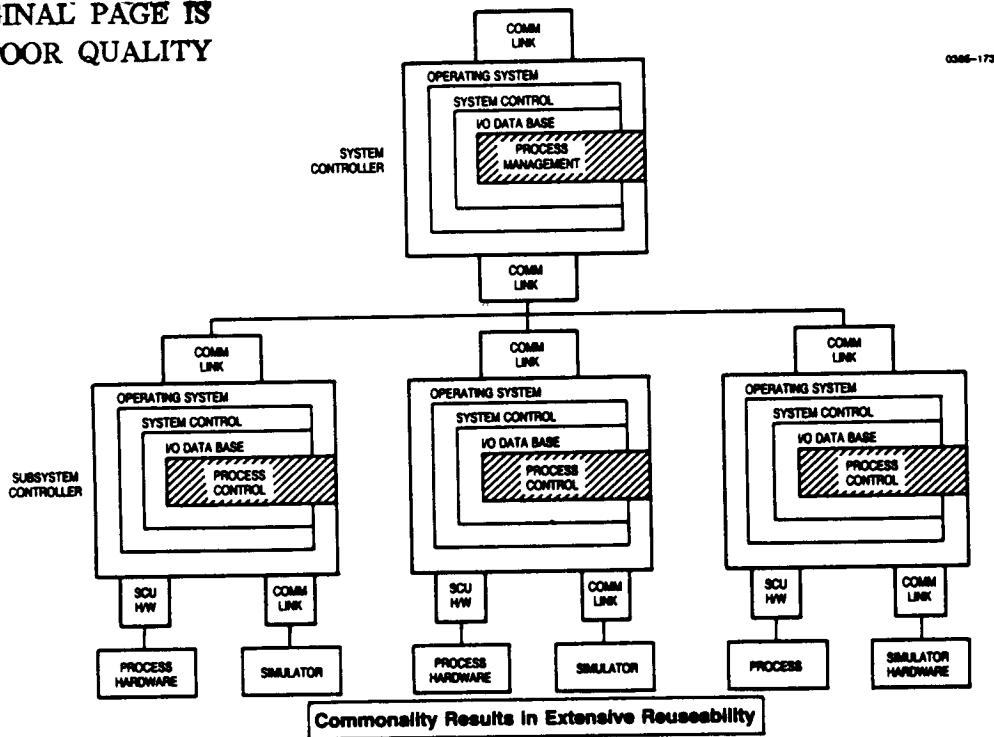


FIGURE 2. Layered Software Architecture Establishes Software Commonality

Many other important benefits are achieved by this layered software approach:

- The application software is completely independent of the automation system target hardware and operating system. This fosters software reusability and portability to any target microprocessor based system and accommodates software testing independent of the automation and controls system development.
- The ASCLSS software architecture was designed to have the application software developed by the subsystem or process expert. Thus, process control responsibility and accountability are retained by the subsystem or process developer, an important Space Station requirement.
- The subsystem controls authority is distributed across the automation hierarchy with maximum controls authority pushed to the lowest or local level which enhances system and process operational autonomy.

The use of real-time simulators of the ARG processes represent an early "proof-of-concept" of TAVERNS (Test And Verification of Remotely Networked Systems) being planned for Space Station. The simulators have the capability to run in real-time and at ten times real-time. They also can program in failures, abnormal performance conditions, and unique operational scenarios with no risk to the process hardware. They fully test the automation and controls system logic before the process hardware is integrated.

In summary, the delivered ASCI SS system demonstrated the automation of 1)three complex life support processes; 2)the monitoring and reporting of ARG system and process status, warning, and alarms; 3)the system event logging; 4)the fault detection and system safing; and 5)the

calculation and evaluation of the current system operational performance parameters and efficiencies.

Distributed/Embedded AI/ES

Space Station's ultimate success will depend heavily on AI/ES. As the Space Station evolves beyond IOC, application of AI/ES will be essential to support:

- Crew operations and scheduling activities.
- Enhanced real-time control procedures and subsystem performance management.
- Fault prediction, detection, isolation, system reconfiguration, and recovery.
- On-orbit maintenance and repair.

The capture of design knowledge and operations history will be required to reduce on-orbit and ground personnel training. The AI/ES will monitor Space Station subsystems, conduct performance trend analyses, and notify the crew of degrading or unsafe conditions well in advance of catastrophic failure. Maintenance will be scheduled when convenient and productive for the crew operations and/or compatible with the logistics schedule.

To meet the cost constraints of Space Station IOC, expert systems and limited levels of artificial intelligence can be embedded in the existing DMS architecture of conventional controllers using conventional software languages such as ADA. These initial AI/ES functions would be used as "controls advisors" and historic data base generators.

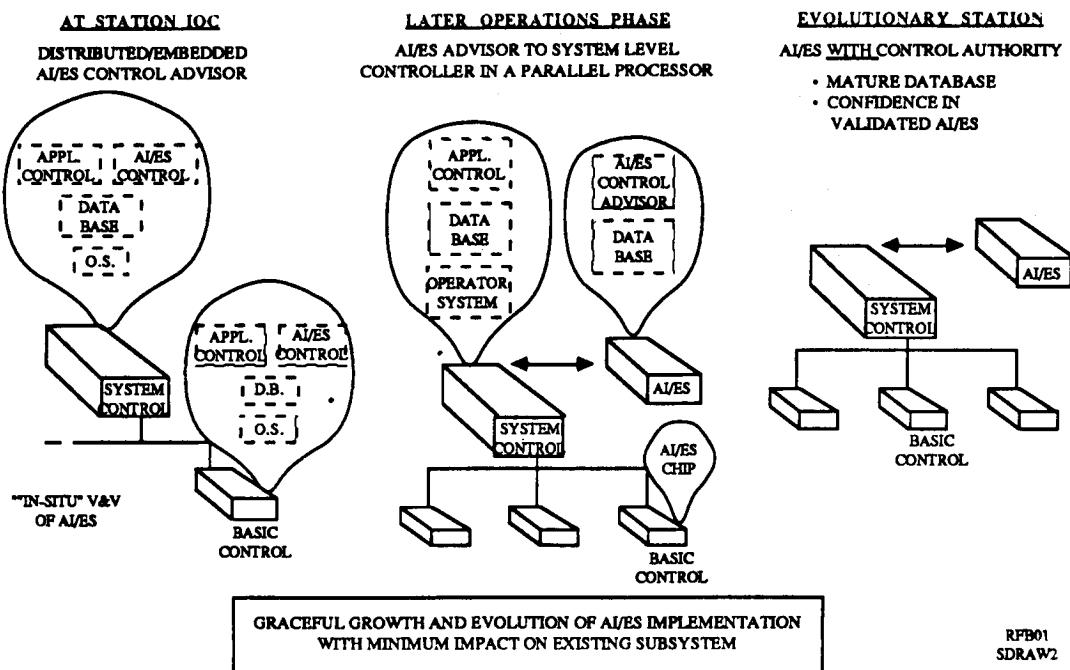


FIGURE 3. Evolutionary AI/ES Implementation on Space Station

The AI/ES advisory functions would be tested and verified by using TAVERNS simulators. Figure 3 describes an approach to implementing AI/ES on the Space Station at IOC and gracefully evolving the level of AI/ES sophistication, control authority, and technology of implementation. As confidence is developed in the AI/ES controls advisor which is being validated "in-situ" in the Space Station operational environment, the AI/ES would be given ever increasing levels of control and command authority. As the level of functional sophistication grows, the AI/ES would eventually be hosted in parallel special purpose processors or AI chips.

The existing ASCLSS automation system offers a unique opportunity and test bed to demonstrate these principles of distributed, embedded AI/ES in a conventional real-time controls system architecture using conventional languages such as ADA. The real-time ASCLSS controllers have 40% of their CPU throughput in each 100ms minor cycle and 80% of their RAM and ROM memory available for embedded AI/ES "controls advisor" functions such as comparison of process state models, monitoring performance trend data, fault prediction, diagnosis, system reconfiguration, and recovery. The table driven, layered software is uniquely structured to accommodate the AI/ES functions at each controller in the hierarchy as merely another task in the application software program. The distributed, embedded AI/ES provides a high level of autonomy and a very responsive advisory function to the real-time process controllers.

Conclusions

The ASCLSS automation system has extended the proven approaches to industrial and commercial automation and control into the unique environment and high performance requirements of the future permanently manned Space Station. The recently delivered ASCLSS has successfully pioneered many of the important features planned for Space Station including commonality of hardware and software, implementation of standards, incorporation of high levels of operational autonomy, and the placement of the crew operator into supervisory control. The system also represents an early Space Station test bed which will support evaluation of subsystem controls requirements, application of ADA software to real-time control, and development of embedded AI/ES in a distributed automation and controls system.

Ten years from now, as astronauts and civilians are living and working on the Space Station, the Earth bound world will undoubtedly take this significant achievement for granted. The automation principles demonstrated by the ASCLSS system represent an early benchmark and significant first step to this successful operational Space Station in the mid-1990's.